



FEMA RISC

14 March 2001, Maynard, MA

River Ice Jams and Mitigation in New England

Ice Engineering Research Group
RS/GIS/Water Resources Branch

US Army Cold Regions Research and Engineering Laboratory

CRREL



Cold Problem Solvers for the World



Key difference: higher stages occur more rapidly and at lower discharges during ice jam events than open water events

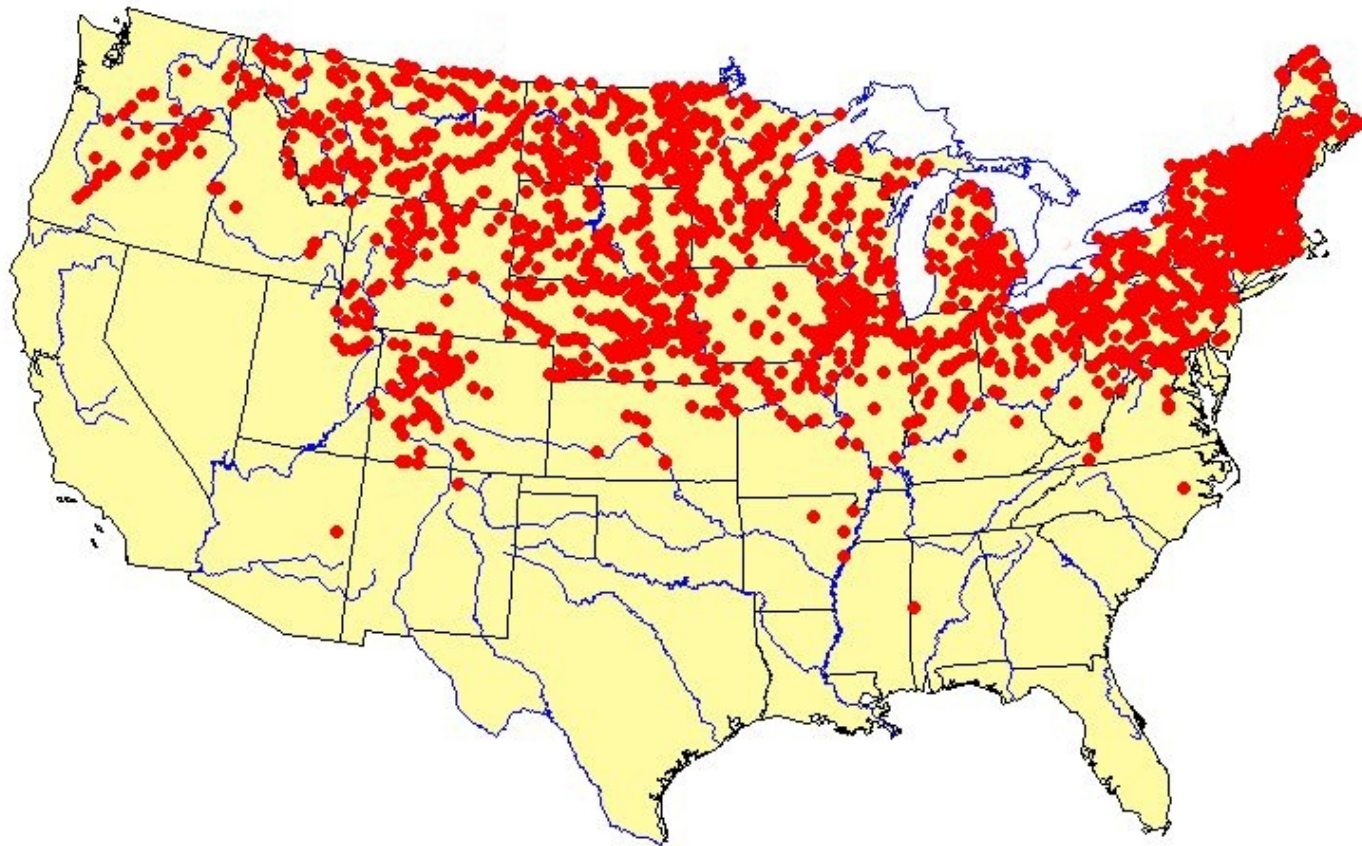
IAHR Working Group on River Ice Hydraulics Definition

An ice jam is a stationary accumulation of fragmented ice or frazil that restricts flow

Ice Jam Formation

- **Jams are possible wherever an ice cover forms**
- **Jams occur at locations where the river's transport capacity is exceeded**
 - **Intact ice cover**
 - **Sharp bends**
 - **Decreases in channel slope**
 - **Constrictions**
 - **Confluences**
- **Ice jam flooding can be extremely rapid**
- **Two types of jams: freezeup and breakup**

Reported Ice Jams



CRREL Ice Jam Database

Overview of New England Ice Jams

- **2079 New England ice events listed in the CRREL ice jam database (17.3%)**
- **1780-1999 (2000 jams not in yet)**
- **289 rivers**
- **422 towns**

ICE ENG. FAC.
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SECTION 206: FLOOD PLAIN MANAGEMENT ASSISTANCE

**HISTORICAL ICE JAM FLOODING IN MAINE,
NEW HAMPSHIRE AND VERMONT**

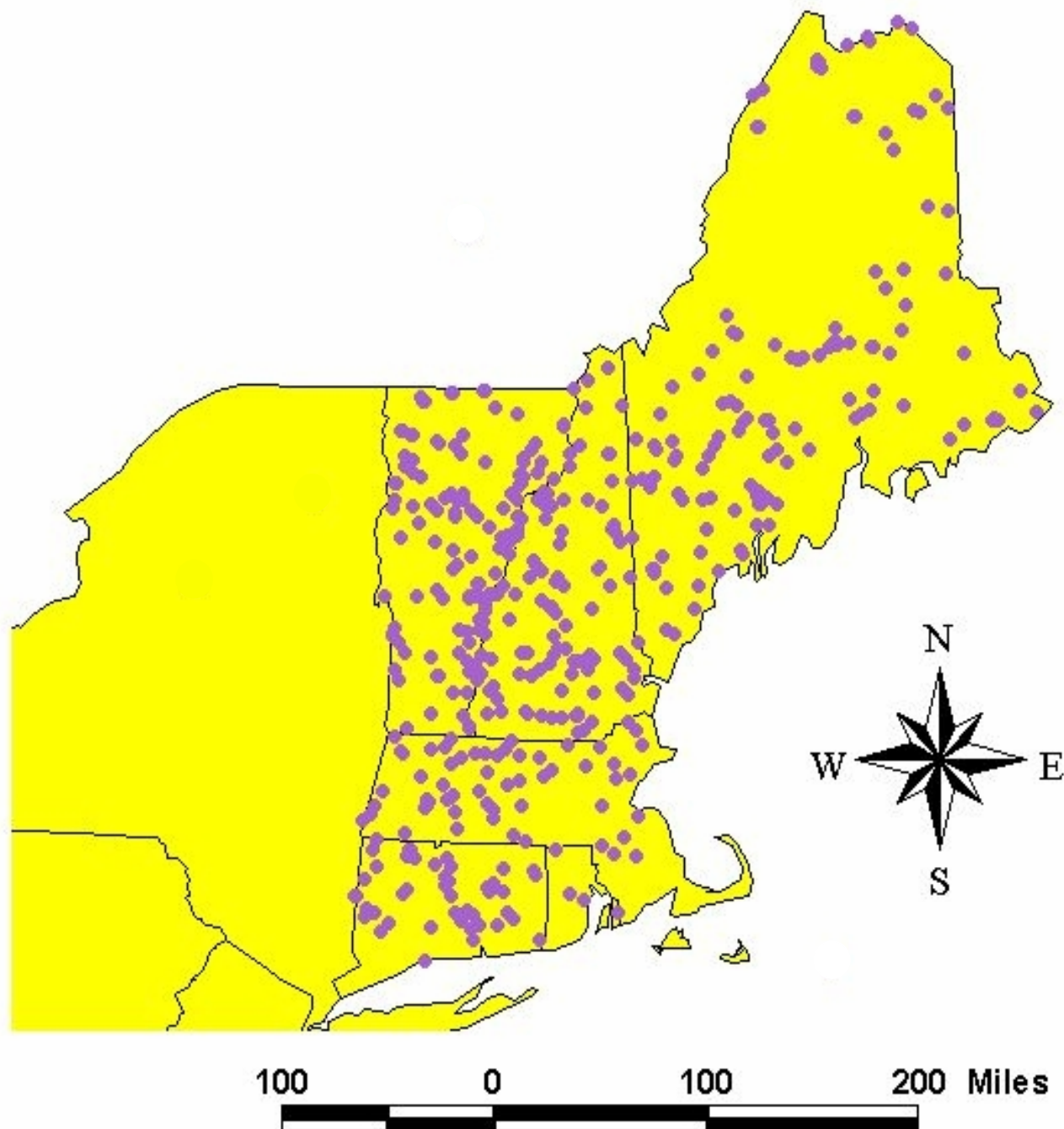


**United States Army
Corps of Engineers**

*...Serving the Army
...Serving the Nation*

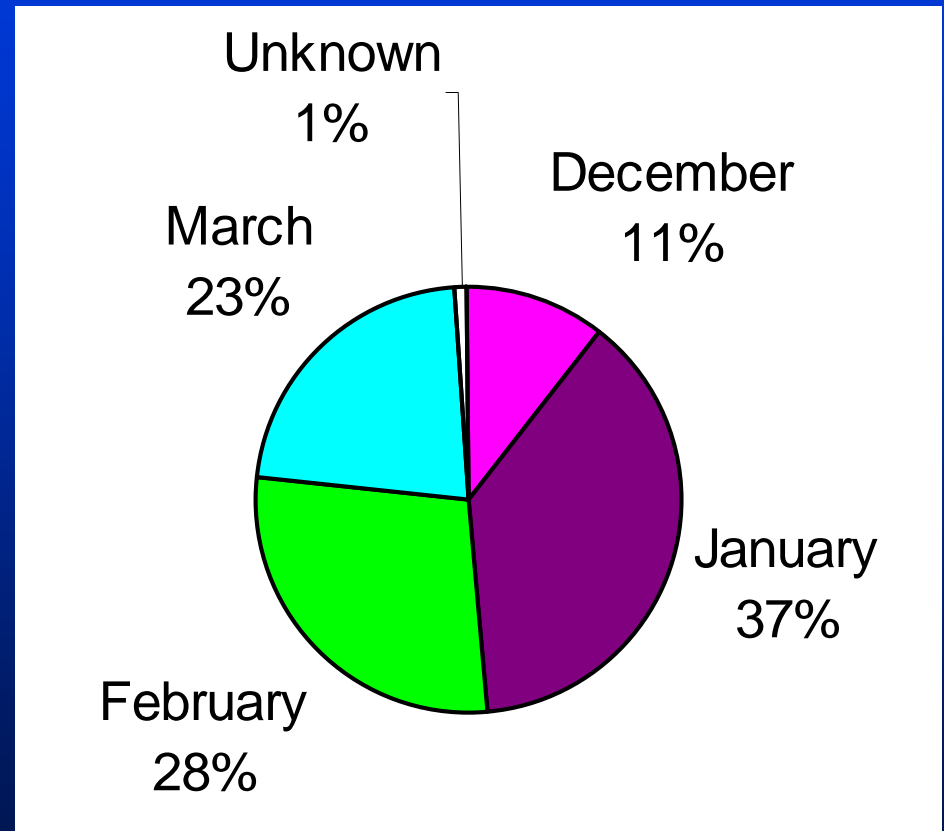
New England Division

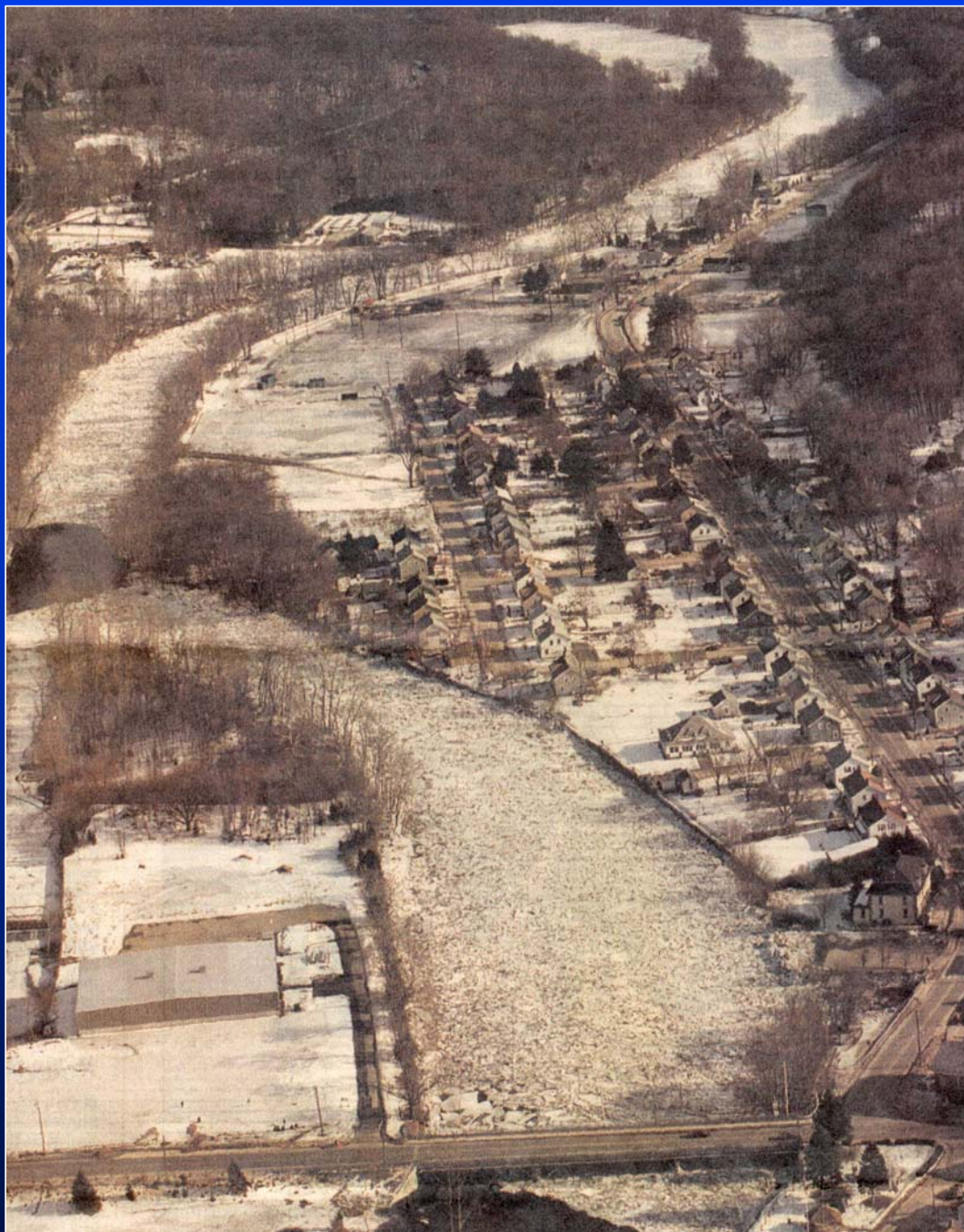
OCTOBER 1980



Connecticut

- 128 jams
- 1902-1999
- 22 rivers
 - Housatonic (22)
- 37 towns
 - Gaylordsville (14)
 - Riverton & Thomaston 12 each

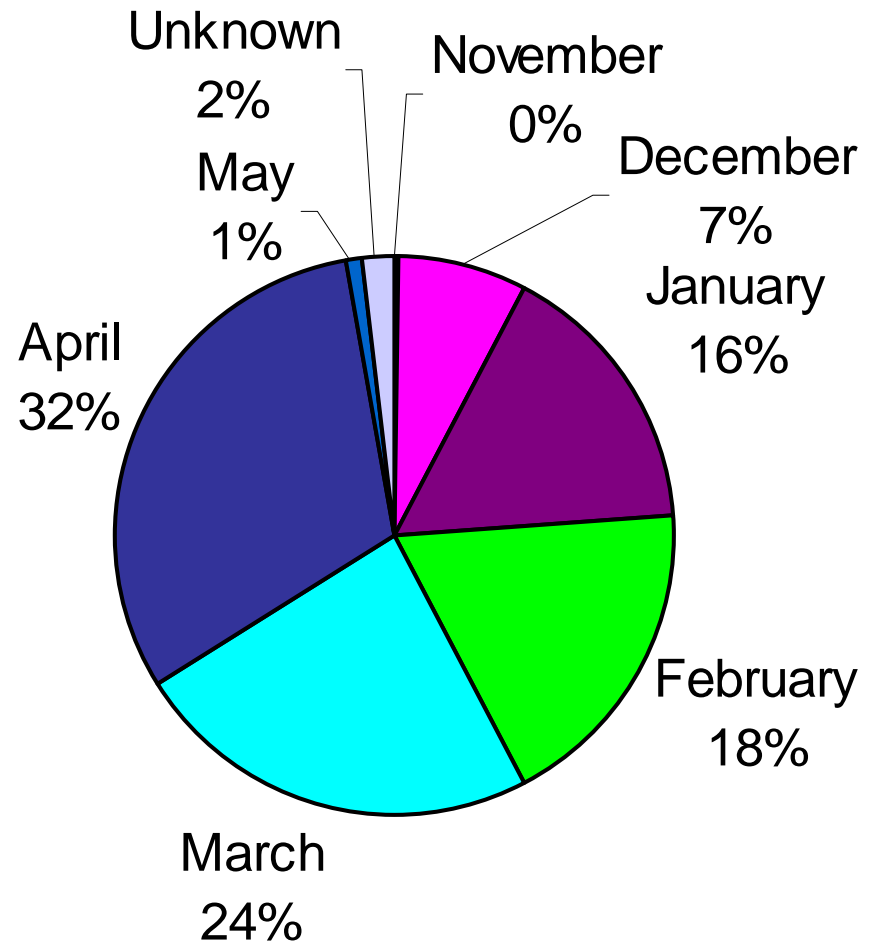




**Shetucket River,
Baltic, CT
02/01/94**

Maine

- 483 jams
- 1780-1999 (1 in 2000 so far)
- 72 rivers
 - St. John (59)
 - Aroostook (54)
 - Kennebec (47)
- 111 towns
 - Dickey (34)
 - Washburn (22)
 - Fort Fairfield (20)

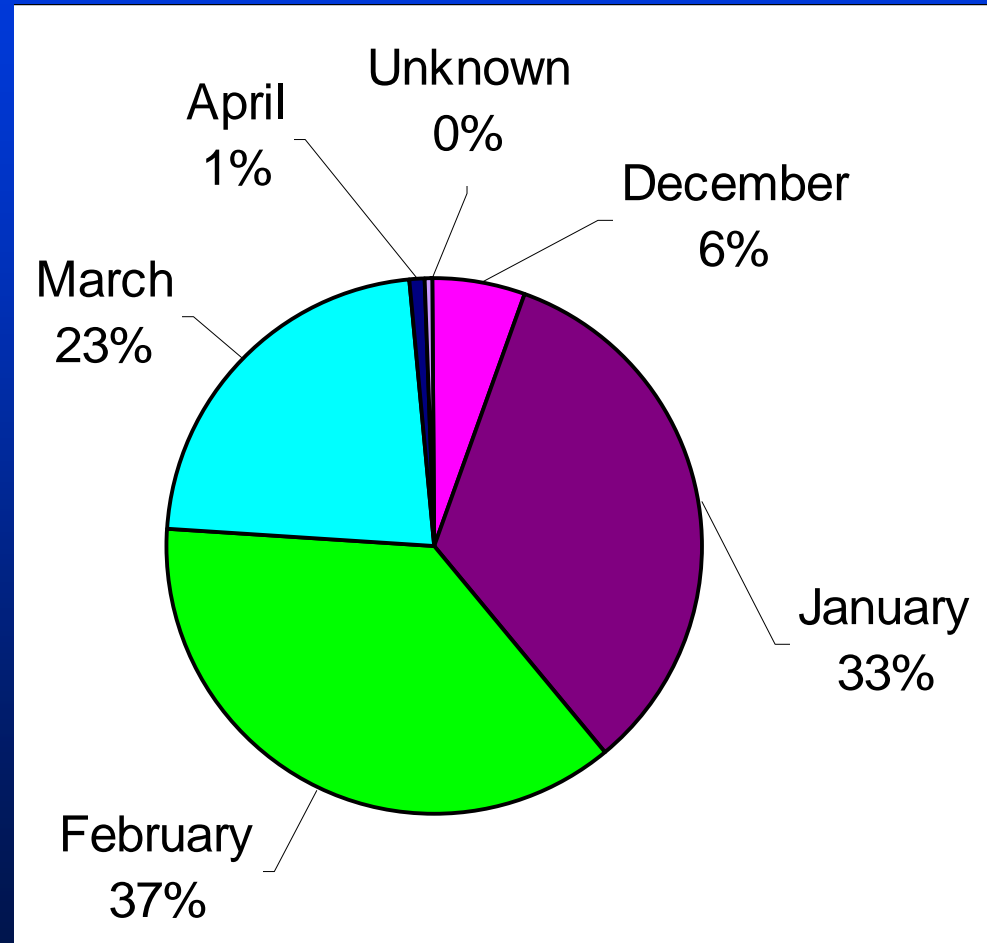




St. John River at Dickey, ME, April 1991 \approx \$14M

Massachusetts

- 211 jams
- 1913-1999
- 45 rivers
 - Millers River (20)
 - West Branch Farmington (18)
 - Middle Branch Westfield (16)
- 53 towns
 - New Boston (18)
 - Goss Heights (16)

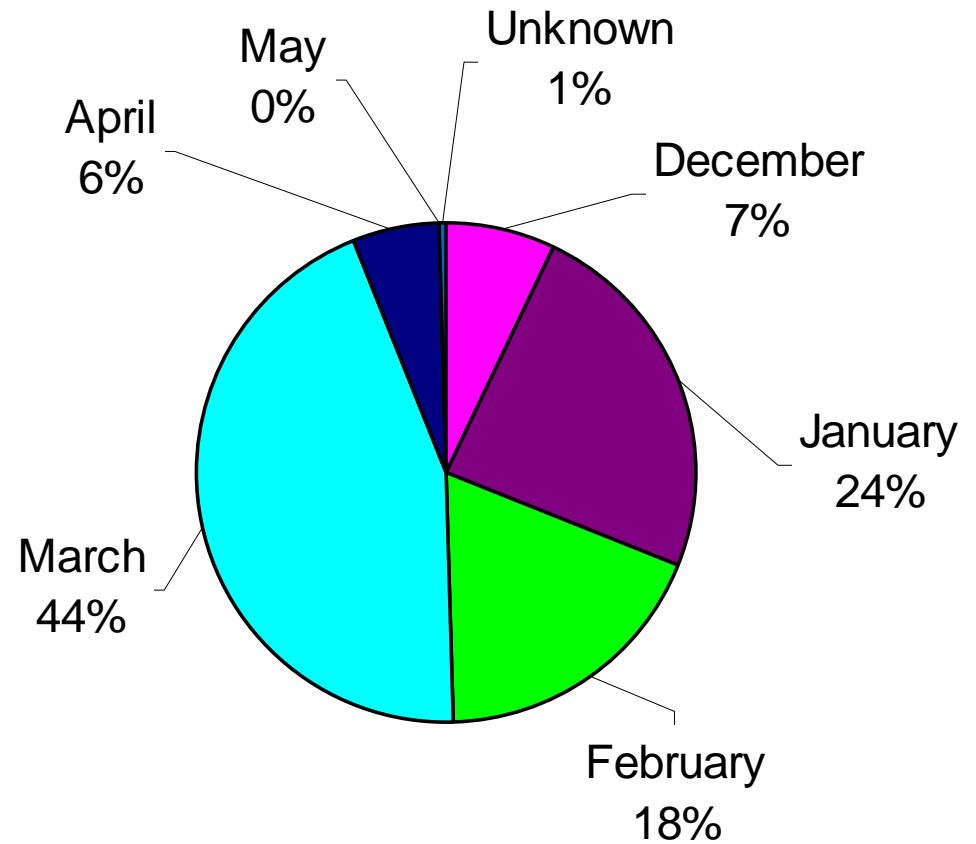


Rhode Island

- 10 jams
- 1941-1972
- 5 rivers, 5 towns
 - Adamsville (Adamsville)
 - Nipmuc (Harrisville)
 - Pawcatuck (Westerly)
 - Potowomut (E. Greenwich)
 - S. Br. Pawtuxet (Washington)
- January = 2
- February = 4
- March = 5
- April = 1
- Unknown = 1

Vermont

- **753 jams**
- **1867-1999**
- **74 rivers**
 - Winooski River (73)
 - Lamoille River (69)
 - Missisquoi River (63)
- **127 towns**
 - East Georgia (51)
 - Montpelier (46)
 - East Barre (45)





Winooski River, Montpelier VT, 03/11/92 ≈ \$20M



New Hampshire

- 495 jams
- 1886-1998
- 71 rivers & streams,
1 lake
- 89 towns



US Army Corps
of Engineers.

Ice Engineering

U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

Ice Jams in New Hampshire

An ice jam is an accumulation of ice in a river that restricts water flow and may cause backwater that floods low-lying areas upstream from the jam. Areas below the ice jam can also be affected when the jam releases, sending water and ice downstream. Damages resulting from ice jams can affect homes, buildings, roads, and riverine structures; block hydropower and water supply intakes; and decrease downstream discharge (Fig. 1).

Roads may be flooded and closed, or bridges weakened or destroyed, limiting emergency and medical relief to the affected areas. The potential exists for death or serious injury due

to jam and flood conditions, as well as during evacuations and other ice mitigation operations. Ice movement and ice jams also can severely erode streambeds and banks, with adverse impacts on fish and wildlife habitat.

Engineers at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) have been working to develop and optimize low-cost structural and nonstructural techniques to prevent or alleviate damages caused by ice jams. Many of these methods, such as early warning systems, ice dusting, ice breaking, ice weakening, and ice jam removal techniques, can be carried out by local

agencies at a reasonable cost (Corps of Engineers 1994).

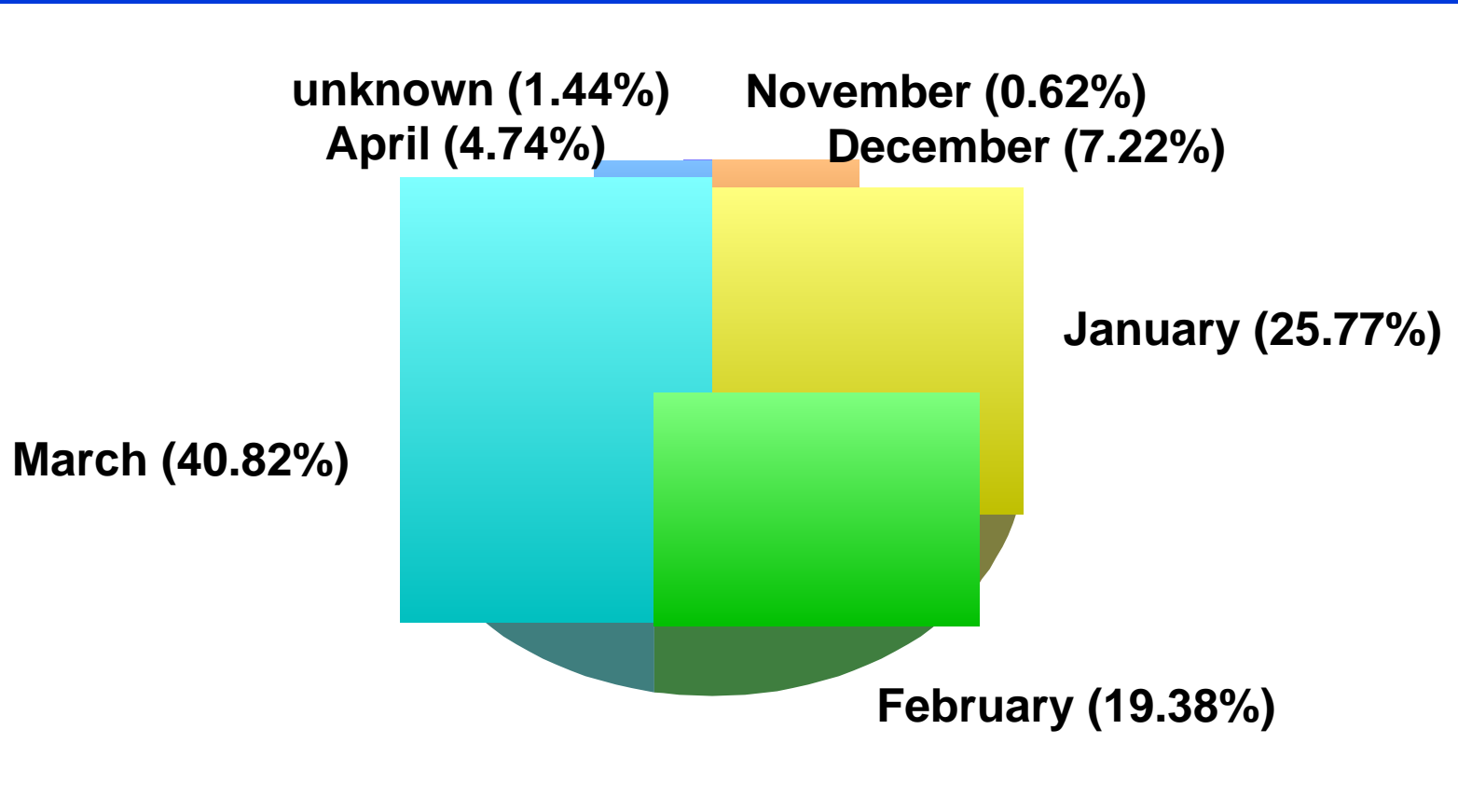
The success of ice mitigation efforts depends upon accurate and reliable ice event data for previous ice events that can be used to predict and assess conditions that may increase the probability of an ice jam formation, and to document steps taken by engineers and relief officials in previous years when confronted with ice jam conditions during emergency situations. The CRREL Ice Jam Database was developed to provide a centralized record of ice events, and now contains information on more than 12,200 ice events, with the earliest account dating from 1780.

Database entries include the name of the water body; the city and state where the ice event took place; date of the event, if known; the ice event type, if known; a brief description of damage; the names of CRREL and Corps personnel familiar with the event or site; reference to visual records of the event, if available; latitude and longitude; USGS gage number, if available; and hydrologic unit code.

Records also contain narrative descriptions of ice events (some of which can be several pages) and a list of information sources. There is a separate database entry for each discrete ice event at a given location. Many entries rely on yearly USGS Water Resource Data Reports and other USGS gaging station data. Information also comes from newspapers, books, historical records, and trip reports.



Figure 1. Shear wall left behind following failure of the January 1999 ice jam on the Israel River in Lancaster, New Hampshire. Note ice on low steel of bridge. (Photograph courtesy of www.greatnorthwoods.org.)





**March 22, 1968
Israel River
Lancaster, NH
\$3 million**



Shear wall left behind at new bridge, Israel River, Lancaster, 01/24/99

River Floods, Ice Sweeps Cars Into River

By SALLIE GRAZIANO
And RICHARD BATEMAN
Valley News Writers

CLAREMONT — A wall of ice crashed over the dam above Dartmouth Woolen Mills at 7:45 this morning, plunging a dozen cars into the river.

Downstream, police and firefighters evacuated several mobile homes in Beauregard Village, Cote's Motel, and an undetermined number of homes near the river.

There were no reports of injuries from the flood damage.

State Civil Defense officials were sent from Concord to assess the damage and to determine whether the National Guard should be called in. The State Police were called in to help handle traffic.

Ice that collected at the brink of the dam above Dartmouth Woolen Mills washed over without warning, according to employees.

"All of a sudden people started hollering, 'Get your cars out of the parking lot,'" said Bob Williams Jr. "I was just glad I could get mine out of there. They had to get one guy out with a bucket loader because he was trapped in his car trying to get it out of the parking lot and they got washed away with the ice." Twenty cars in the lot were damaged, including the 12 that were swept into the river. Several of the cars were nose up in the river.

Police hadn't started removal of the cars
(Continued on page 16)

FLOODING



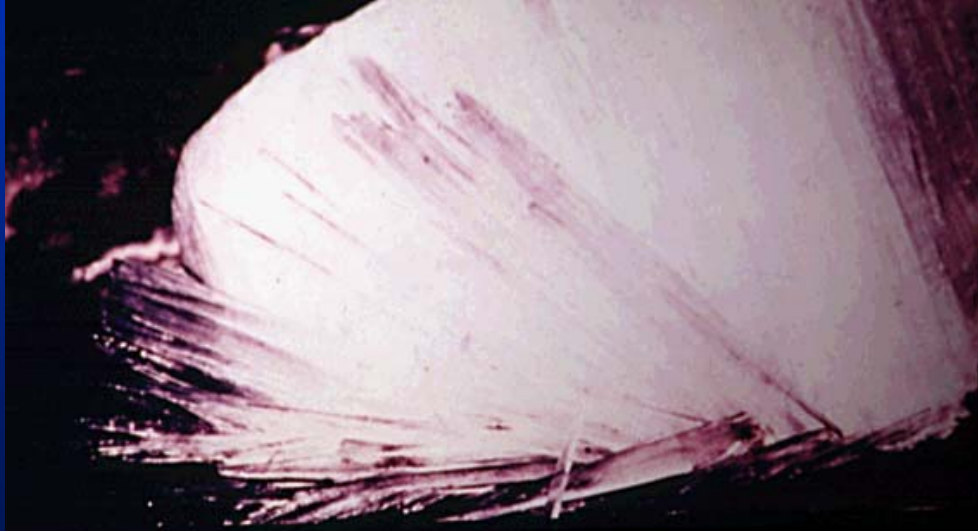
Valley News — Tom Wolfe

A dozen cars are now parked in the Sugar River, which flooded over its banks this morning in Claremont.

**February 16, 1984 Sugar River, Claremont, NH
(one death in 1981 jam)**

Basic Ice Processes

- Ice covers made up of two ice types
 - Columnar
 - Fine-grained)
- Once formed, ice cover thickens due to thermal and/or mechanical processes
 - Can result in freezeup jams
- Ice cover breakup caused by thermal and/or mechanical processes
 - Can result in breakup ice jams



• **Columnar ice:** Thermally-grown “black” ice, transparent, allows solar penetration, decays into “candled ice”



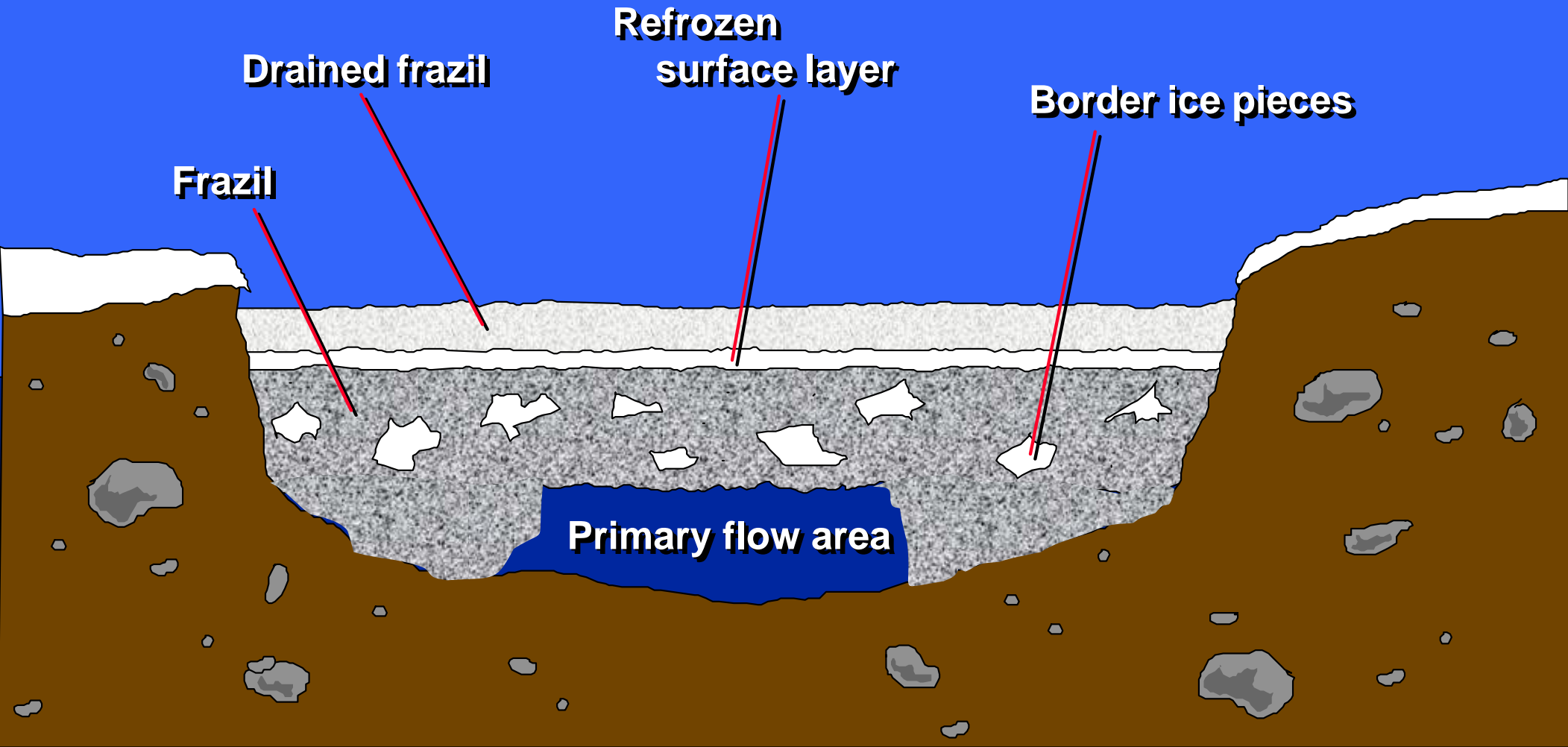
• **Fine grained ice:**
made of frazil or
snow, looks “white”,
resists solar
penetration

Freezeup Jams

- **Early to mid-winter formation**
- **Subfreezing air temperatures**
- **Frazil and broken border ice**
- **Unlikely to release**
- **Fairly steady water flow**
- **Smooth to moderate surface roughness**



Cross Section of Freezeup Jam



River Ice Cover Breakup

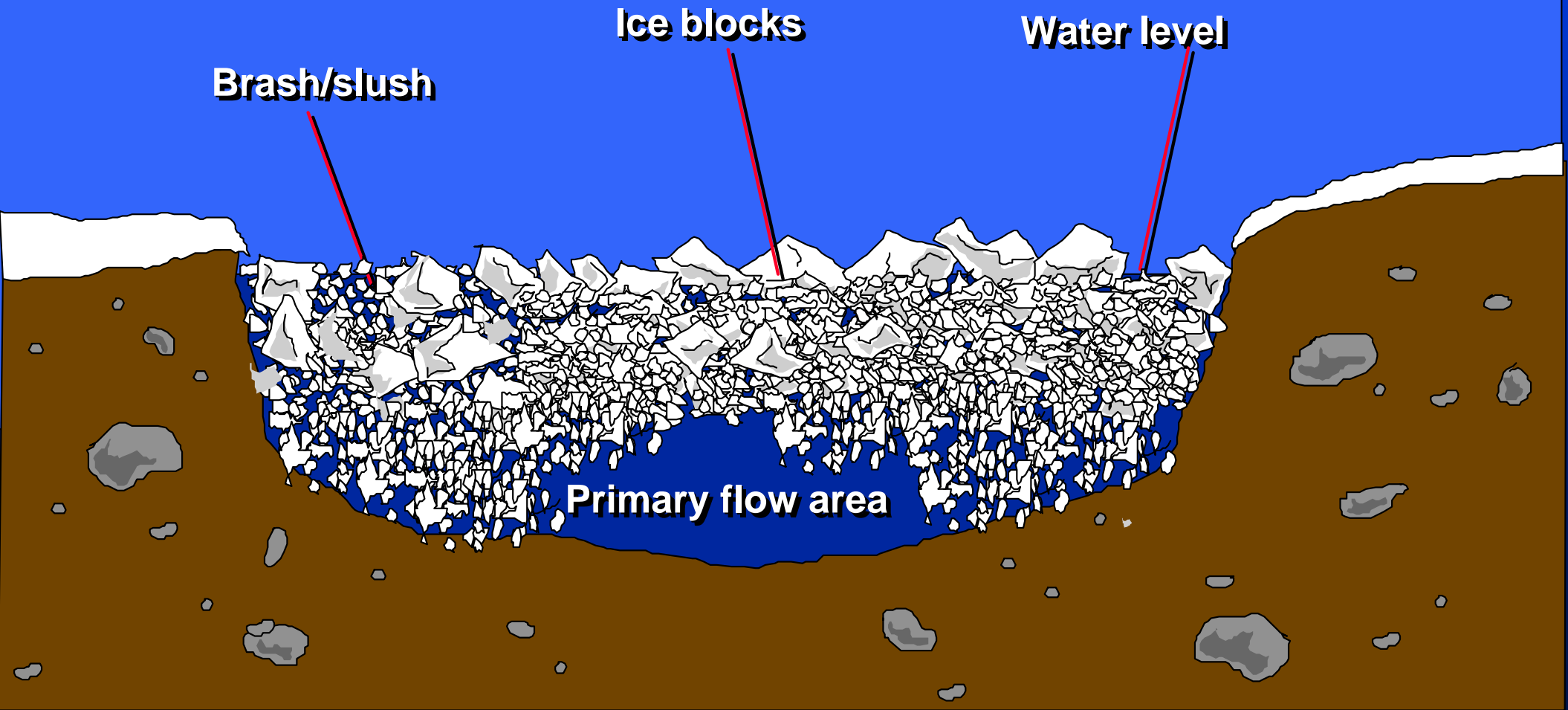
- **Thermal Breakup: Ice cover melts in place**
 - Direct sunlight plays a large role
 - Surface color influences absorption of sunlight: Dusting ice promotes melting
 - Water on ice decreases reflection, may promote melting
 - Open water areas absorb sunlight
- **Mechanical Breakup: Hydrodynamic forces acting on cover exceed cover strength**
 - Results from an increase in flow
 - Precipitation event
 - Snowmelt event
 - Dam operation

Breakup Jams

- **Mid to late winter formation**
- **May form more than once per season**
- **Near-freezing air temperatures**
- **Broken sheet and border ice**
- **Highly unstable, releasing suddenly**
- **Unsteady water flow (surges)**
- **Moderate to extreme surface roughness**
- **Midwinter jams may refreeze, causing additional problems later in the winter**



Cross Section of Breakup Jam



Ice Jam Mitigation

- **Advance Measures**
- **Emergency Measures**
- **Permanent Measures**
- **Freezeup Jam Control**
 - Control production and transport of frazil ice
 - Displace jam initiation location
- **Breakup Jam Control**
 - Control timing of ice breakup
 - Displace jam location

Mitigation Goals

- **Advance Measures**
 - Flood protection
 - Reduce ice supply
 - Control breakup sequence
 - Increase conveyance
- **Emergency Measures**
 - Flood Protection
 - Increase Conveyance
 - Remove Ice
- **Permanent Measures**
 - Flood protection
 - Reduce ice supply
 - Increase conveyance
 - Control breakup sequence
 - Displace ice jam location



Goal: avoid evacuations under conditions like this

Middlesex Blames Montpelier For Flooding

By ERICA HOUSKEEPER
Times Argus Staff

MIDDLESEX — Residents are blaming Montpelier officials for failing to notify them of potential flooding that stemmed from ice-breaking procedures on the Winooski River in the capital Friday.

Homes on Three Mile Bridge Road were invaded by flood waters on Friday night after Montpelier officials began to break up ice on the river to create a channel of water near the Interstate 89 exchange.

The channel prevented ice from backing up in Montpelier and in Berlin.

"It was not an attempt to damage someone else's property," Montpelier City Manager Bill Fraser said this morning.

Montpelier Police Chief Douglas Hoyt said that flooding was imminent. "My response is, whose ice is it? Berlin's? East Montpelier's? Who notified us? We have a plan, and we followed it."

But Middlesex homeowners contend that the flooding could have been prevented if their town officials had received proper notice from Montpelier officials.

After the flooding occurred, the Middlesex Volunteer Fire Department assisted residents, who plan to bring their concerns to a regularly scheduled Middlesex select-board meeting tonight at 7.

"It's a situation where Montpelier flushes the toilet onto us," said Amy Welti-Darling, who bought her home on Three Mile



Devil Mountain Times Argus

Jeffrey Darling surveys the damage around his home on the Three Mile Bridge Road in Middlesex. Rising waters in the nearby Winooski River flooded the home and left massive ice chunks and debris in the yard.

Jeffrey, have flood insurance for their home, they do not have insurance for their home.

inson's wife, Shelly, and their three children are staying with relatives in East Montpelier.

this is not the first time this has happened," she said, referring to the flood of 1992.

“Residents are blaming Montpelier officials for failing to notify them of potential flooding stemming from ice-breaking procedures on the Winooski River in the capital Friday.”

Advance Measures

- **Non-structural intervention**
- **Two weeks to six months lead time**
- **Can be inexpensive**
- **Effective?**
- **Includes monitoring, early warning, ice weakening**

Background Data Collection

- **Ice records**
- **Historical ice and stage data**
- **River geometry**
- **River hydraulics**
- **Hydrology**
- **Meteorology**
- **Flooded areas**
- **Past flood-fighting measures**
- **Potential flow control**

Sources of Background Information

- **CRREL and Corps reports**
- **Topographic/GIS mapping**
- **USGS gage data**
- **NWS forecasts**
- **Historical ice jam and open water flood data (stages, flood areas)**
- **CRREL ice jam database**
- **Technical reports**
- **Local civil defense unit reports**
- **State emergency agency reports**
- **Newspaper/TV accounts**
- **Photographic/videotape**
- **Anecdotal records**

96-1

SPECIAL REPORT



Ice Jam Flooding and Mitigation Lower Platte River Basin, Nebraska

Kathleen D. White and Roger L. Kay

January 1996



US Army Corps
of Engineers
Pittsburgh District

Local Ice Related Flood Problem Investigation Detailed Project Report



Allegheny River
Oil City, Pennsylvania

29

CRREL and Corps Reports

AFTER-ACTION REPORT

ICE CONDITIONS

WINTER 1965-1966




U. S. ARMY ENGINEER DISTRICT, ROCK ISLAND

CORPS OF ENGINEERS
CLOCK TOWER BUILDING
ROCK ISLAND, ILLINOIS

AUGUST 1967

24



Ice Jam Database

State Name:

City Name:

River Name:

USGS Gaging Station number: Hydrologic Unit Code:

Beginning Month: Calendar Year: to





Ending Month: Calendar Year: or

One Month: ☒ Calendar Year
☐ Water Year

Jam Type:

Optional:

Match: Output Format: Publications: Description:

Press for
information

Press to submit a new entry



River Ice Information

In order to achieve the NERFC mission, we require close cooperation and interaction between a number of weather forecast offices. These offices include [Buffalo NY](#), [Binghamton NY](#), [Albany NY](#), [Brookhaven NY](#), [Burlington VT](#), [Taunton MA](#), [Gray ME](#), and [Caribou ME](#). Since river ice floods are very local in nature, people in ice jam prone areas should stay in touch with local officials during periods of impending danger.

The National Weather Service in cooperation with local officials periodically provides watches and warnings.

[Flood Watches and Warnings](#)

To effectively combat the potentials of river ice problems, the NERFC is experimentally setting up a river ice monitoring network. This network is composed of concerned citizens, local emergency managers, and government officials, who periodically report on the characteristics and the development of river ice during the winter/early spring season. Below are links to some of their contributions.

Latest Ice Reports

-  [Western New York](#)
-  [Eastern New York](#)
-  [Southern New England MA/CT/RI](#)
-  [Vermont](#)
-  [New Hampshire](#)
-  [Maine](#)

[SUBMIT A REPORT](#)

Current Conditions

-  [Mean Daily Air Temperature Map](#) from NOHRSC.
-  [Thawing Degree Days](#)
-  [Freezing Degree Days](#)

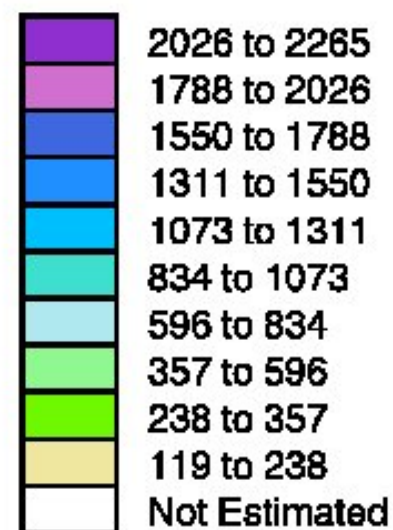
www.nws.noaa.gov/er/nerfc/ice

FREEZING DEGREE DAYS

Oct 1, 2000 to Mar 8, 2001

Northeast River
Forecast Center

CUMULATIVE DEGREE DAYS (F.)



86.93 W



NH-VT STREAM STAGE & FLOWS AT SELECTED STATIONS

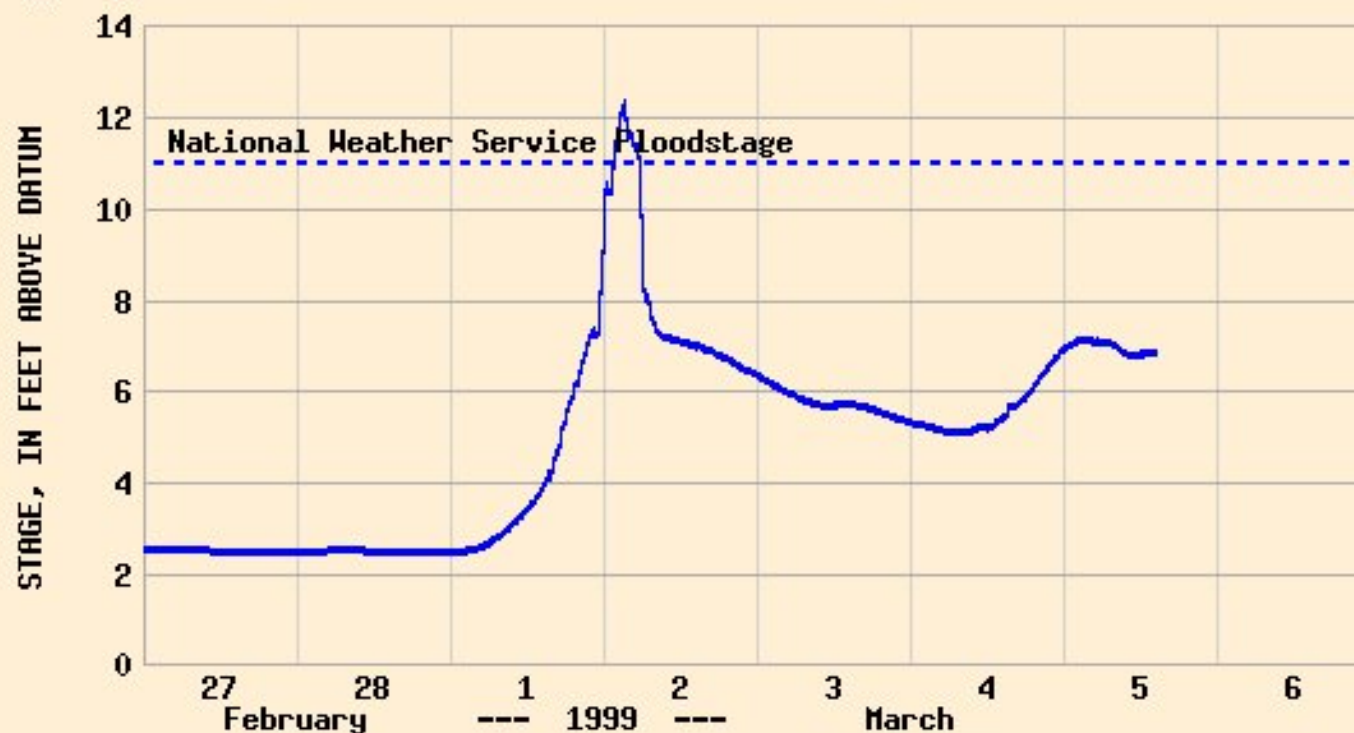
Updated Fri Mar 5, 1999 15:47

Sites marked by asterisk (*) have dial-up modems used to download stage data. These modems are called once daily and all new data is downloaded. Because of this, these sites are only updated one time each day on the web page.

[PROVISIONAL DATA SUBJECT TO REVISION](#)--Select a station number to view graph(s) and other data for the station.

Station		Long-term			
Number	Station Name	mean flow			
		03/05	Flow	Stage	Date/Time
● Androscoggin River Basin					
01052500	DIAMOND R NR WENTWORTH L NH	130	Ice	5.26	03/05 12:30
01053500	ANDROSCOGGIN R AT ERROL, NH	1910	1690	2.47	03/05 13:00
01054000	ANDROSCOGGIN R NR GORHAM NH	2280	3160	4.56	03/05 14:00
● Saco River Basin					
01064500	SACO R NR CONWAY NH	453	3030	5.51	03/05 13:00
01064801	BEAR CAMP R NR TAMWORTH, NH	100	Ice	5.66	03/05 13:30
● Piscataqua River Basin					
01072100	SALMON FALLS R @ MILTON NH *	197	981	4.72	03/05 04:00
01073500	LAMPREY R NR NEWMARKET, NH	367	898	4.57	03/05 12:45
01073587	EXETER RIVER NR BRENTWOOD NH*	--	Ice	6.09	03/05 04:00
● Merrimack River Basin					
01074520	EB PEMIGEWASSET R @ LINCOLN	158	Ice	2.21	03/05 12:44
01075000	PEMIGEWASSET R AT WOODSTOCK	281	Ice	4.44	03/05 14:00

Stage -- updated Fri Mar 5 14:30 1999 -- [download presentation-quality graph](#)



- [Data used in graph](#)
- [Historical daily mean or peakflow data for this station](#)
- [Return to Current Streamflow Conditions table](#)

Station Description

01031500 PISCATAQUIS RIVER NEAR DOVER-FOXCROFT, MAINE

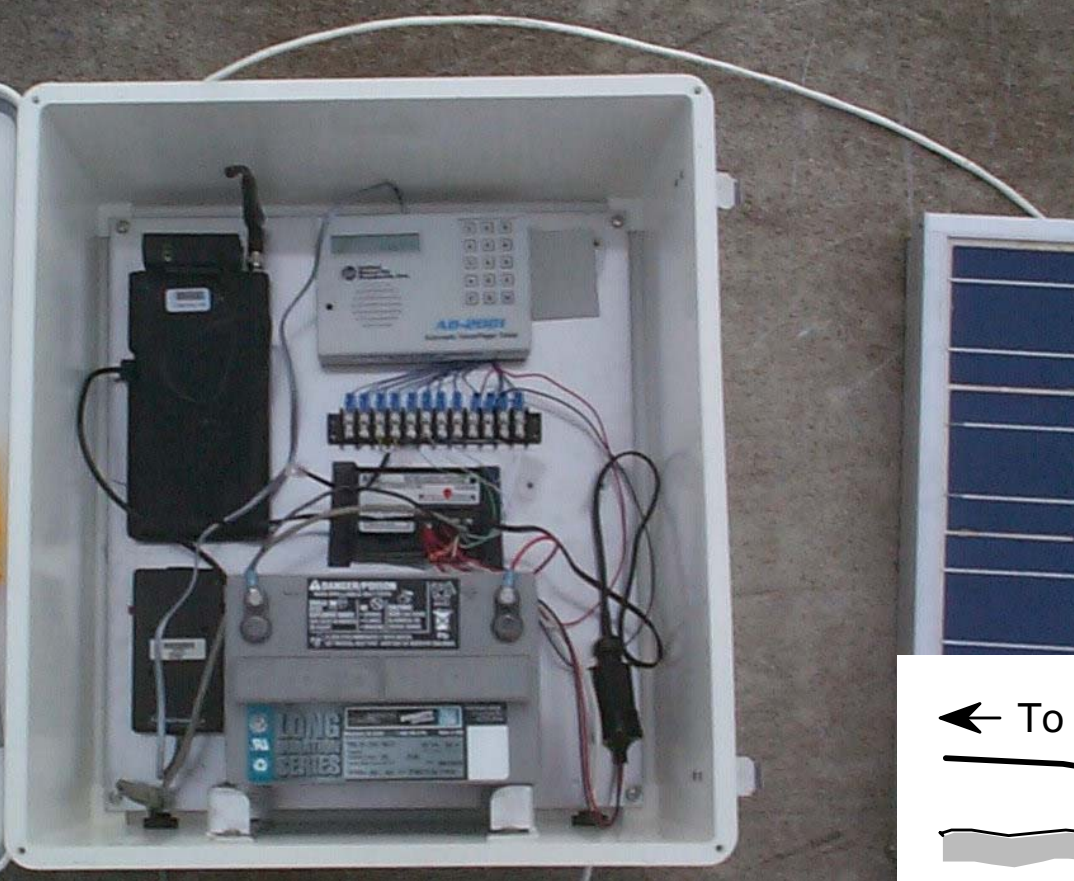


Early Warning

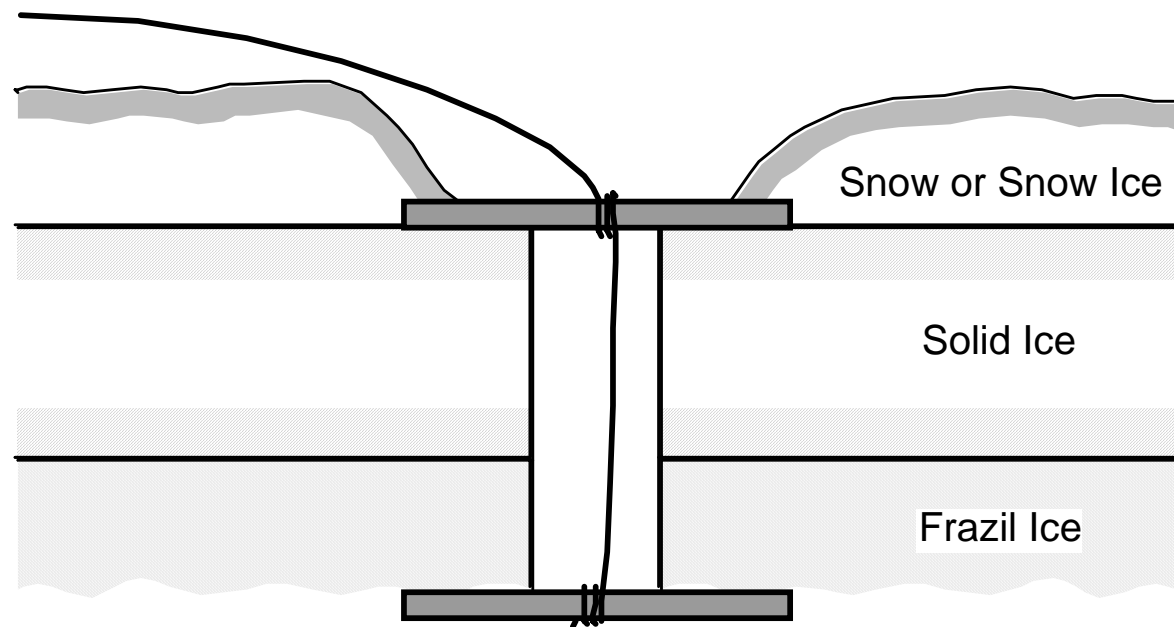
- Provides critical information
- Two weeks to several months lead time
- Inexpensive and invaluable
 - Trained observers
 - Part of emergency response team
 - Track pre-event ice conditions and during event
 - Helpful for after-action assessment
 - Ice motion detectors
 - Trip wires in ice
 - alarms inform emergency managers
 - select locations to give days/hours warning
 - Can be remote
 - Automated alarming stage gauges

Aerial photographs





← To Ice Motion Detector

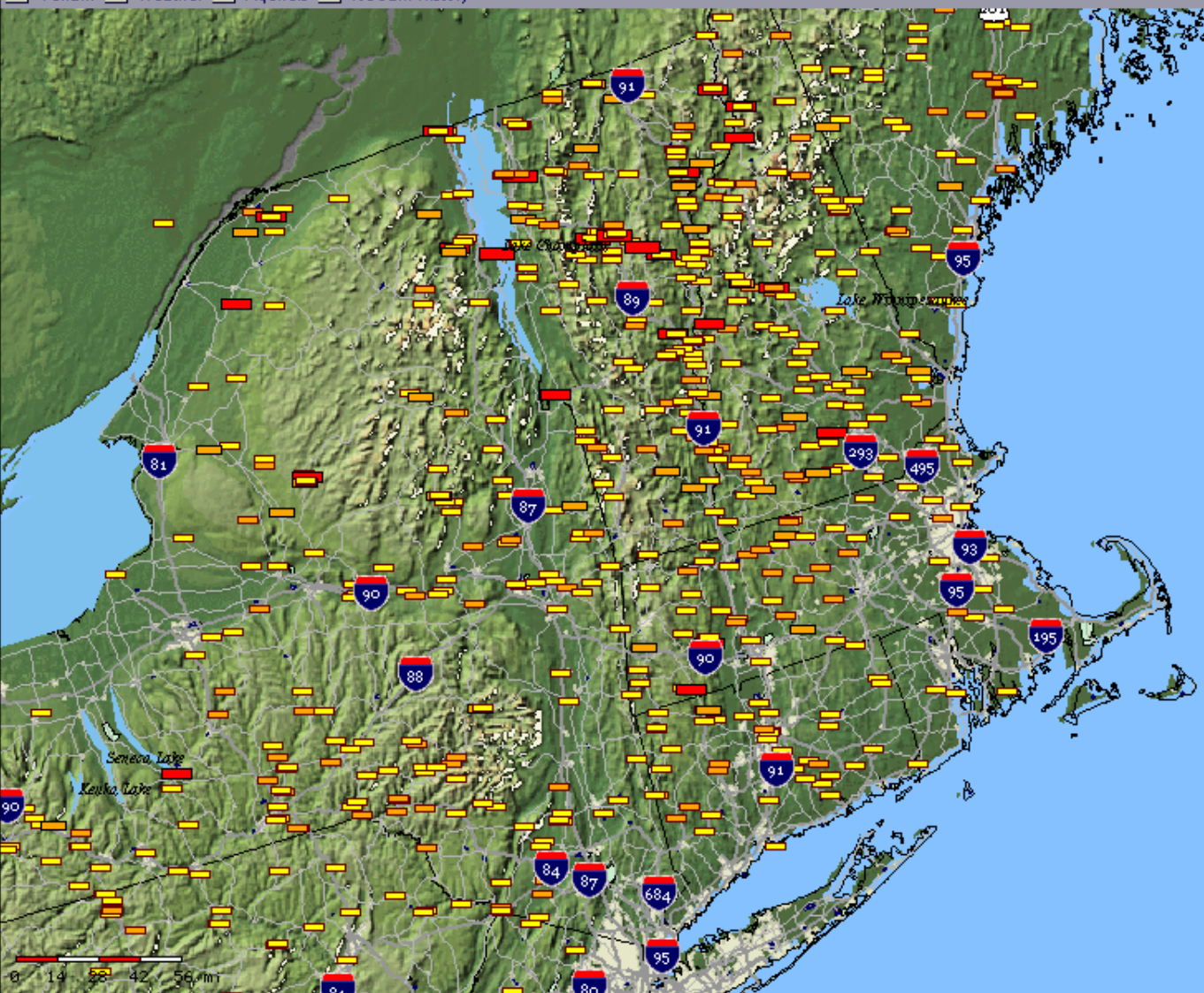




Prediction

- **Models difficult to construct**
 - Empirical
 - Statistical
- **Require reasonable ice data sets**
 - Ideally about 50% ice, 50% open-water
 - Montpelier
- **Flood Potential Index**
 - Currently under development with support from USACE, USGS, NWS

☒ States ☐ USACE Military Boundaries ☐ EPA Regions ☐ Congressional ☐ Federal Land ☐ Native Land ☐ Flood Risk ☐ Cities
☒ Terrain ☐ Weather ☐ Aquifers ☒ Ice Jam History



U.S. Army Corps of
Engineers

Remote Sensing &
Geographic Information
Systems

Map Size:

800x600

Projection

Lambert

Set Scale:

Pan

Filter Properties:

District/Division:

All

Filter State:

VT

clicking on map will: get property info ☐ pan/zoom ☒



your click (lat, lon): 44.999991 -100.000013

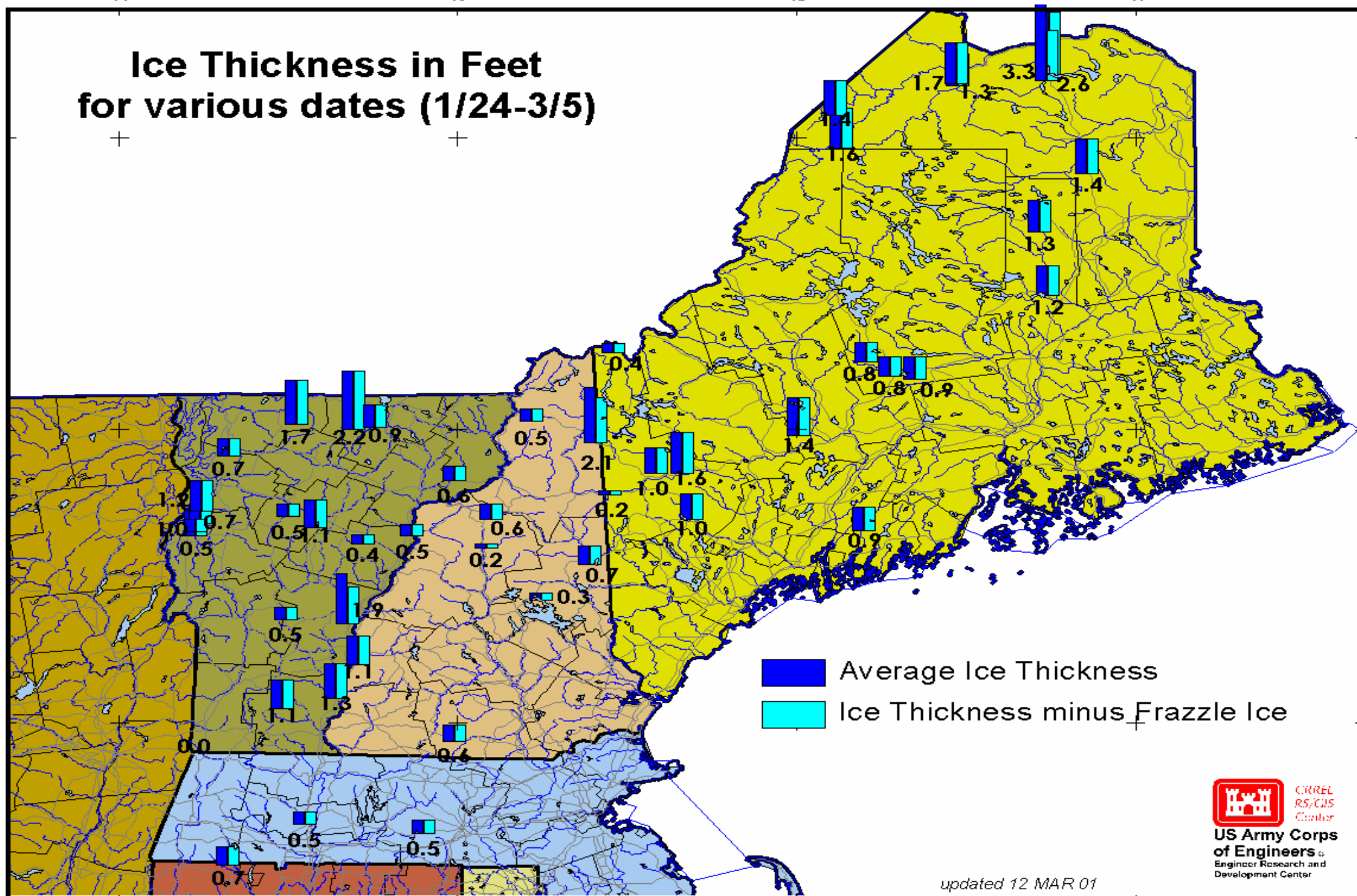
-  1 - 3 Ice Jams
-  4 - 9 Ice Jams
-  10 - 15 Ice Jams
-  16 - 30 Ice Jams
-  31 - 50 Ice Jams
-  Airport
-  Military Base
-  Urban Area

[Reset Map](#) | [Printable Map](#) | [Printable Map](#) | [FUDSMIS Home](#) | [Help!](#) | [Search by Property Name](#) | [Search by Congressional District](#) |

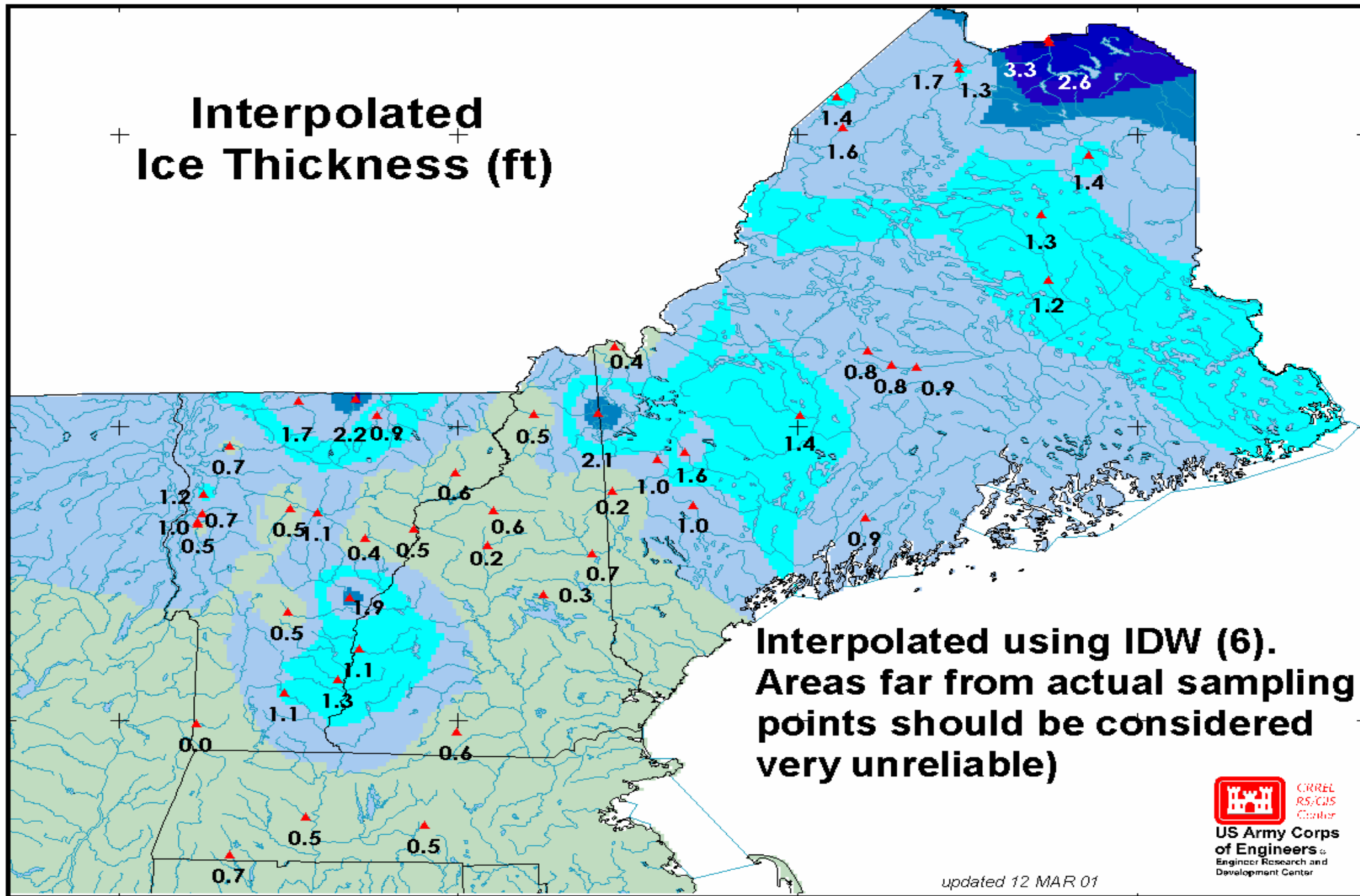
Quick Search By: City, State: , or Zip Code: or Property Number:

1808152.293384 -126732.146853 2516808.710625 404967.612122

Ice Thickness in Feet for various dates (1/24-3/5)



Interpolated Ice Thickness (ft)



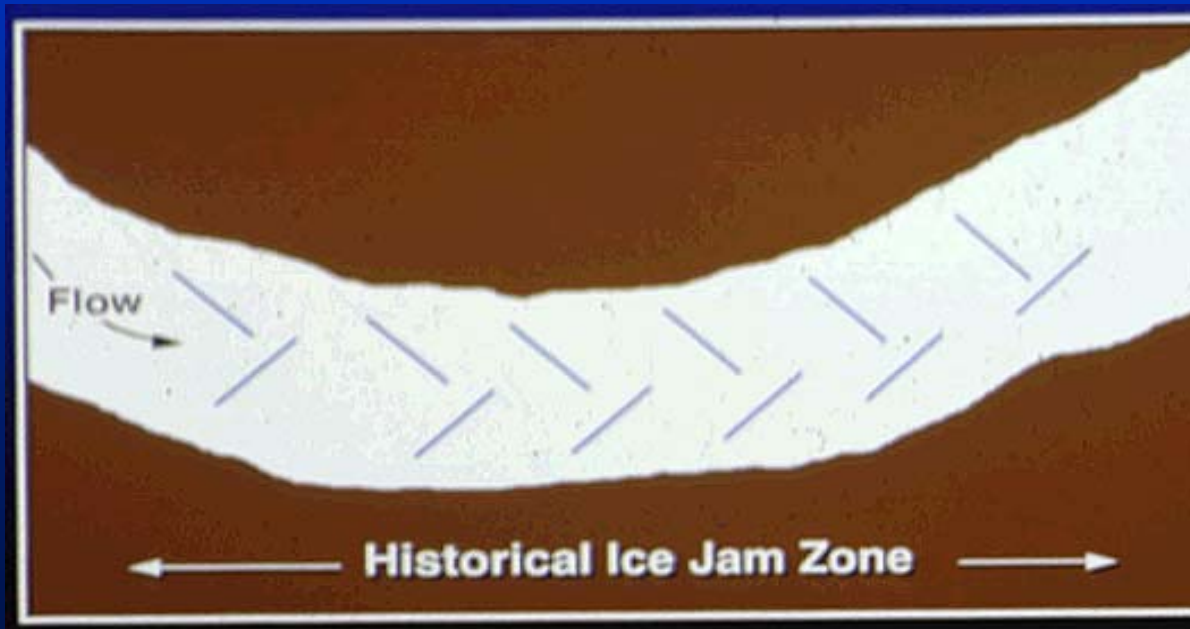
Interpolated using IDW (6).
Areas far from actual sampling
points should be considered
very unreliable)

Advance Measures: Ice Weakening

- **Mechanical: Immediate strength reduction**
 - Ice cutting
 - 4WD trencher
 - amphibious ice saw
 - Ice breaking
 - amphibious excavator
 - vessels
- **Thermal: Accelerate natural ice deterioration**
 - Hole drilling
 - Dusting

Ice Cutting

- Beaurivage River, Quebec
 - 4WD trencher
 - diagonal slot pattern, center 2/3
 - ice moves through cut area



Ice Breaking

- Icebreakers/towboats
 - can clear channels in jams
- hovercraft
 - effective for sheet ice



Hole Drilling

- Oconto River, WI
 - 10 ft grid, central 2/3 of channel
 - holes expand to weaken sheet
 - ice moves into Lake Michigan



Aerial Dusting

- Yukon River, AK
 - sand increases solar absorption
 - 25 years, high productivity
 - difficult to assess effectiveness



Emergency Measures

- Jam in place
- Cost & effectiveness depend on timing
 - try to minimize damages
 - time is critical
- Excavation
- Blasting
- Flood Fighting
- Do nothing
- Lead time = effectiveness

Excavation

- **Most efficient when stage rising**
- **Pre-positioned equipment helpful**
 - excavator, clam-shell, bulldozer
 - clear channel D/S of toe
 - dislodge key pieces at toe
- **Expensive to excavate ice pieces after stage falls**
- **Can be combined with blasting (excavate where safe, blast upstream end of jam)**

Excavation Examples

- Gorham, NH



- Morrisonville, NY



Diversion Channels



Emergency diversion channel: Lancaster, NH

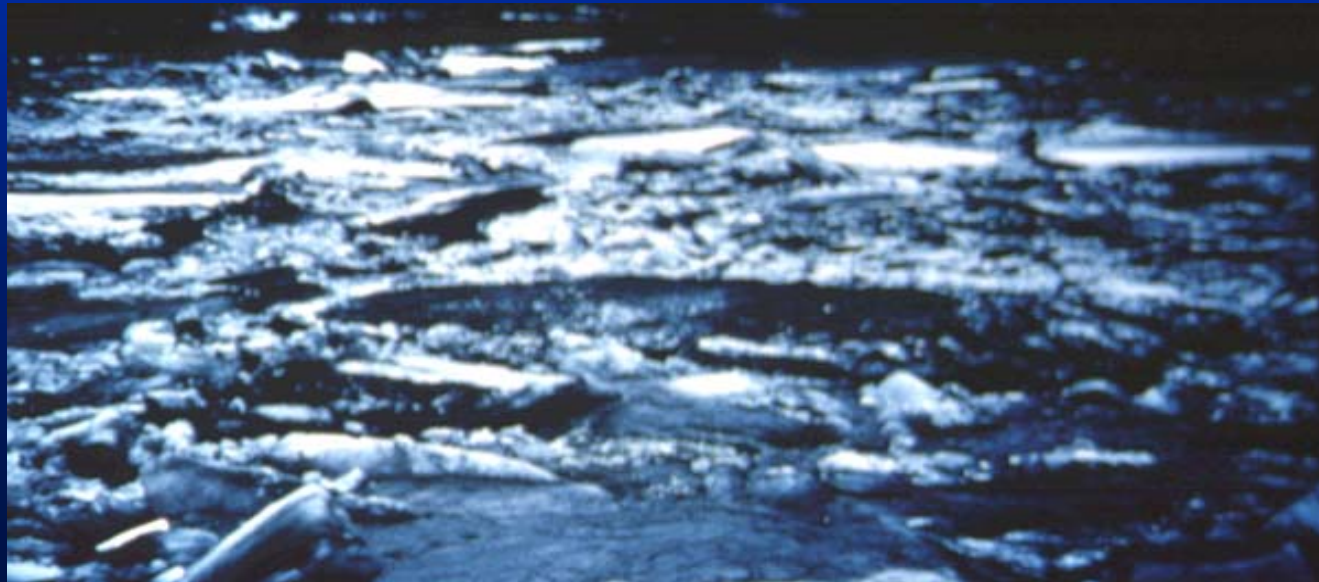
Blasting

- Requires open water downstream
- Work from downstream to upstream
- Charges should be placed just under ice
- Pre-planning needed (liability issues, rapid response)
- Not suitable for urban area



Do Nothing

- Thin, weak ice
- Little remaining ice supply
- Continued mild temperatures
- Late season jam (check records)
- Other constraints

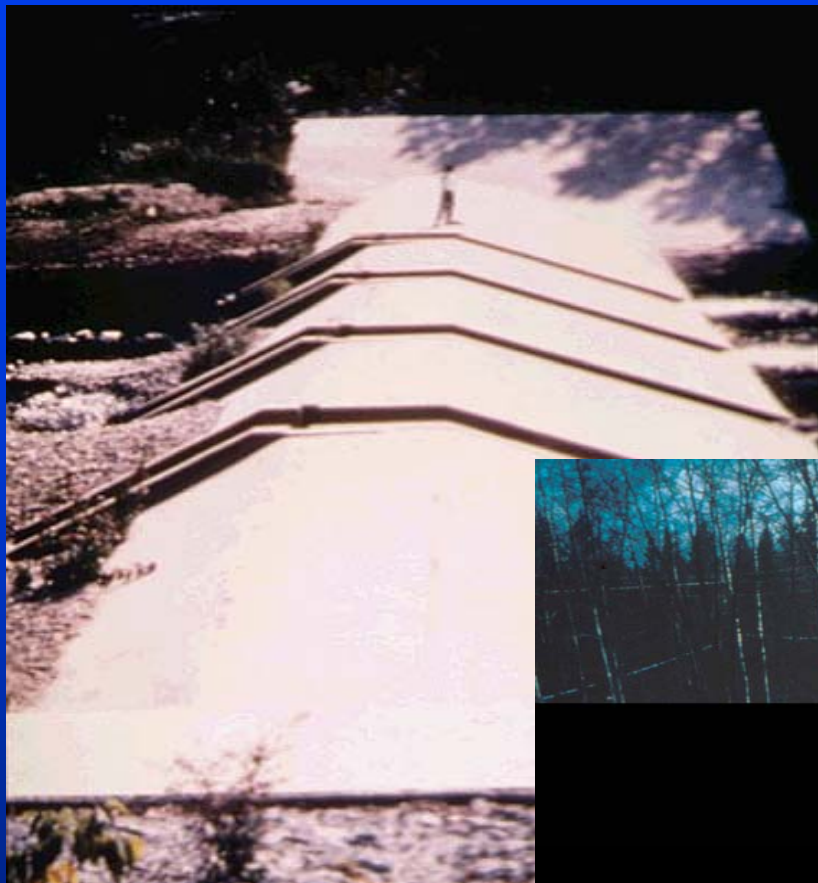


Permanent Measures

- **Structural solutions**
 - Ice control structures (ICS's)
 - Diversion channels
 - Flow control
 - Thermal discharge
 - Levees, floodwalls
 - Flood proofing
 - Land management
- **2-5 year lead time**
- **Expect high benefits and reliability**
- **Generally costly although some low-cost solutions are under development**

Ice Control Structure, Lamoille River, Hardwick, VT





Israel River ICS, Lancaster, NH

Retaining Ice

- Porous structure retains ice in or near channel
- Flow allowed through or around, decreasing upstream stages



Conventional Mitigation - Freezeup & Breakup

- **Levees, floodwalls**
 - set-back levees preferred
 - design for ice forces
 - often more expensive than ICS
- **Floodproofing**
 - effective for localized flooding

Conventional Mitigation - Freezeup & Breakup

- **Land management**
 - green belts, parks
 - zoning & building codes
 - riparian vegetation (control ice & erosion)

Structural

	Jam Type Technique	Type of Mitigation
Dikes, levees, floodwalls	F,B	P
Dams and weirs	F,B	P
Ice booms	F,B	P,A
Retention structures	B	P
Channel modifications	F,B	P
Ice storage zones	B	P,A

Nonstructural

Forecasting	F,B	A,P
Monitoring and detection	F,B	E,A,P
Floodproofing	F,B	P
Sandbagging	F,B	A,E
Evacuation	F,B	A,E
Levee closing	F,B	A,E
Thermal control	F,B	E,A,P
Land management	F,B	P
Ice cutting	B	A
Operational procedures	F,B	A,P
Dusting	F,B	E,A
Ice breaking	F,B	E,A
Mechanical removal	F,B	E,A
Blasting	F,B	E,A

**Key: B=Breakup jam, F= Freezeup jam, P= Permanent measure
A= Advance measure, E= Emergency measure**